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Identifying Prospective Areas for Groundwater Potential Zone in Allahabad City

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Abstract

Groundwater is an important resource contributing significantly in total annual supply. However, overexploitation has depleted groundwater availability considerably. Assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems. Integration of Remote Sensing data and the Geographical Information System (GIS) for the exploration of groundwater resources has become a breakthrough in the field of groundwater research, which can assists in assessing, monitoring, and conserving groundwater resources. The accurate information to obtain the parameters that can be considered for identifying the groundwater potential zone are found to be geomorphology, slope, Landuse/landcover and lithology. In this study weighted overlay method is utilized in ArcGIS environment. Suitable ranks are assigned for each category of these parameters. This procedure is repeated for all the other layers and resultant layers are reclassified. About 43.44 km^2 of the total area falls under the 'very poor' zone, 21.56 km^2 falls under 'poor' zone, 18.89 km^2 falls under moderate zone and 12.61 km^2 is come under 'very good' groundwater potential zone. The excellent groundwater potential zone is concentrated in the north-eastern and north-east region of the study area due to the distribution of alluvial plains and agricultural land with high infiltration ability. This groundwater potential information will be useful for effective identification of suitable locations for extraction of water. The study was found to be useful in conserving natural resources which are depleting at high rates due to the pressure and demand of increasing population.

Keywords: *Groundwater potential, Remote sensing &GIS, Weighted overlay Technique*

1. INTRODUCTION

Groundwater represents the second-most abundantly available freshwater resources and constitutes about 30% of global fresh water resources (Subramanya, 2008). Ground water contributes to about 80% of the drinking water requirements in the rural areas, 50% of the urban water requirements and more than 50% of the irrigation requirements of the nation. Hence it plays a fundamental role in human well-beings, as well as that of aquatic and terrestrial ecosystems. Because of its several inherent qualities it has become an immensely important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries.

Currently groundwater exploration isgaining more attention due to uneven and untimely distribution of rainfall, which ultimately leads towards regular drought events, less availability of rural and urban water supply, poor irrigation management etc. Over the years the growing importance of groundwater based on an increasing need has led to unscientific exploitation of groundwater creating a water stress condition. This alarming situation calls for a cost and time effective technique for proper evaluation of groundwater resources its planning and management.

Remote sensing data with their advantages of spatial, spectral and temporal availability and manipulation of data covering large and inaccessible areas within a short time have become very handy tools in accessing, monitoring and conserving groundwater resources. GIS and remote sensing tools are widely used for the management of various natural resources (Dar *et al*. 2010; Chaube *et al*. 2011; Krishna Kumar *et al.* 2014; Magesh *et al.* 2014a,b). Delineating the potential groundwater zones using remote sensing and GIS is an effective tool. In recent years, extensive use of satellite data along with conventional maps and rectified ground truth data has made it easier to establish the base line information for groundwater potential zones (Tiwari and

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Rai, 1996; Das *et al.* 1997; Thomas *et al.* 1999; Harinarayana *et al.* 2000; Muralidhar *et al.* 2000; Chowdhury *et al.* 2010). Remote sensing not only provides a wide-range scale of the space-time distribution of observations, but also saves time and money (Murthy, 2000; Leblanc *et al.* 2003; Tweed *et al.* 2007). In addition it is widely used to characterize the earth surface (such as lineaments, drainage patterns and lithology) as well as to examine the groundwater recharge zones (Sener *et al.* 2005).

Allahabad, a major city of Uttar Pradesh state is situated at the confluence of River Ganga and Yamuna. The increasing population of Allahabad is heavily dependent on ground water resources. Over-exploitation of ground water could prove catastrophic in future if corrective measures are not taken in the region. Therefore, the present study focuses on the explicit objective to identify groundwater potential zones in Allahabad city using the advanced technology of remote sensing and GIS for the planning, utilization, administration, and management of groundwater resources.

2. MATERIALS & METHODS

2.1 Study Area Characteristics

Allahabad is located at 25^0 27' N, 81^0 50' E; 25.45^0 N, 81.84^0 E in the southern part of the Uttar Pradesh at an elevation of 98 meters. To its southwest, east and south west is the Bundelkhand region, to its north and north east is the Awadh region and to its west is lower Doab.

Fig. 1: Location map of the study area

2.1.1 Soil

The soil of Allahabad is dominant with alluvial (Entisols) soil, which is fertile but not too moist. The non-doabi parts of the district, the southern part and eastern part of the district are somewhat dry and rocky (similar to adjoining Bundelkhand and Bagelkhand region).

2.1.2 Demography

Allahabad City has a population of 1,042,229 as per the 2001 census. It lists as the 32nd most populous city in India and 3rd fastest growing cities of Uttar Pradesh after Lucknow and Agra. Allahabad has an area of about 7000 km^2.

2.1.3 Climate

Allahabad experiences all four seasons. The summer seasons are from April to June with the maximum temperatures varies from 35^0C to 45^0C. Monsoon begins in early July and lasts till September. The winter seasons falls in the month of December, January and February. Temperatures in the cold weather could drop to freezing with maximum at almost 12^0C to 14^0C. The lowest temperature recorded, 1^0C.

2.1.4 Population

In 2001 census, Allahabad had a population of 4,936,105 of which males were 2,626,448 and 2,309,657 were females. The initial provisional data

released by census India 2014, shows that density of Allahabad district for 2014 is 1,087 people per sq. km. In 2001, Allahabad district density at 901 people per sq.km.

2.1.5 Hydrogeology

Ground water in the district occurs both in alluvium and in the weathered & jointed sandstones areas which are underlain by hard rocks. In the unconsolidated or alluvial formation ground water occurs under unconfined to confined conditions in the shallow and deeper aquifers respectively and depth to water ranges between 2 to 20 meters during pre-monsoon period, while in the post monsoon period it stands between 1 to 18 meters.

2.2 Data Used

2.2.1 Remote Sensing Data

In this studyLandsat ETM+ sensor data were utilized. Since the study area was covered in many paths of Landsat satellite data acquisition (each path is covered separately in a different day as per orbital calendar), cloud free data was acquired in different time windows depending upon the overpass of satellite. Each scene was ortho corrected; geo-referenced and suitable Image enhancements are applied to facilitate the delineation and interpretation of different thematic information. After the processing of data landuse map was prepared for the study area.

2.2.2 Software used

ERDAS imagine 9.4 Software was utilized in varioussteps of satellite image processing and Arc GIS 9.4Software was used in for analysis, database creation, composition and generation of maps.

2.3 Methodology

In the present study a hierarchical process is utilized. The potential sites were selected based on a range of criterions such as landuse/landcover, geomorphology, lithology and slope. The groundwater potential zones were obtained by overlaying all the thematic maps in terms of weighted overlay method using the spatial analysis tool in ArcGIS interface. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight is assigned according to the influence of the different parameters. The weights and rank have been taken as suggested by Krishnamurthy et al 1996. The logical combination of these created layers was utilized in assessing ground water potential sites. The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential feature. As far as slope is concerned, the highest rank value is assigned for gentle slope and low rank value is assigned to higher slope. In LULC high rank is assigned to crop land and low value is assigned to barren land.

3. RESULTS & DISCUSSION

3.1 Land use / Land cover

The satellite data was transformed into thematic land use/land cover map of Allahabad for year 2014 using on screen visual interpretation. The land use land cover map of the study area is shown in fig. 2. Statistics of landuse/cover is depicted Table 1. The different classes of land use/land cover is found to be Built up land (Urban / Rural), fallow land, agricultural crop land, Gullied/Ravines, wasteland, Plantation/Orchards, Scrubland and Water bodies. The total area of Allahabad city is found to be 96.201 km^2 (Table 1). The study area is dominated by Built up land (Urban / Rural) area which contributes about 63.42% of the total area (61.21 km^2). About 3.01 km^2 (3.12%) of area is covered by fallow land. The area covered by crop land is 18 km^2 (18.65%). The area covered by Gullies/Ravines is 0.70 km^2 (0.72 %). The area covered by other wasteland is 1.09 km^2 (1.15%). The area covered by plantation/orchards is 0.76 km^2 (0.79%).The scrub land covers about 1.13 km^2 (1.16%).The area covered by water bodies is 10.69 km^2 (10.99%). The area coverage of water body is high due to the fact that Allahabad city is situated at the confluence of two mighty rivers, the Ganga and the Yamuna.

3.2 Lithology mapping

Figure 3 depicts the lithology and Table 2 exhibits the area statistics of lithology of of the study area. The clay with sand/Silt parting area is found to be 16.31 km^2 (16.90%) of total area (96.51 km^2). The area of clayey sand is 2.45 km^2 (2.54%).The area of gravel/sandy,silt is 5.93 km^2 (6.14%). The settlement area is 63.43% of the study area. The area covered by water body is10.61 km^2 (10.99%).

3.3 Geomorphology mapping

According to the geomorphology the Allahabad city is classified into Alluvial plain, flood plain settlement and water body (Table3, figure 4). The area of alluvial plain is 17.03 km2 (17.65% of total area). The area of flood plain is 7.66 km2 (7.93%). In this respect, the settlement area is 61.21 km2 (63.43%). The area covered by water body is 10.61 km2 which is 10.99% of total area.

Table 1. Area Statistics of Land use / Land Cover Map

Class	Area (km^2)	Area (%)
Built up land / Settlement	61.21	63.42
fallow land	3.01	3.12
crop land	18	18.65
Gullied / Ravince	0.70	0.72
Other wasteland	1.09	1.15
Plantation / Orchards	0.76	0.79
Scrub land	1.13	1.16
Water bodies	10.61	10.99
Total	96.51	100

Table 2. Area Statistics of Lithology of Allahabad city

Class	Area(km^2)	Area (%)
Clay with sand/Silt parting	16.31	16.90
Clayey sand	2.45	2.54
Gravel/Sandy, silt	5.93	6.14
Settlement	61.21	63.43
Water body	10.61	10.99
Total	**96.51**	100

Table 3. Area statistics of Geomorphology of Allahabad city

Class	Area(sqkm)	Area (%)
Alluvial plain	17.03	17.65
Flood plain	7.66	7.93
Settlement	61.21	63.43
Water body	10.61	10.99
Total	**96.51**	**100**

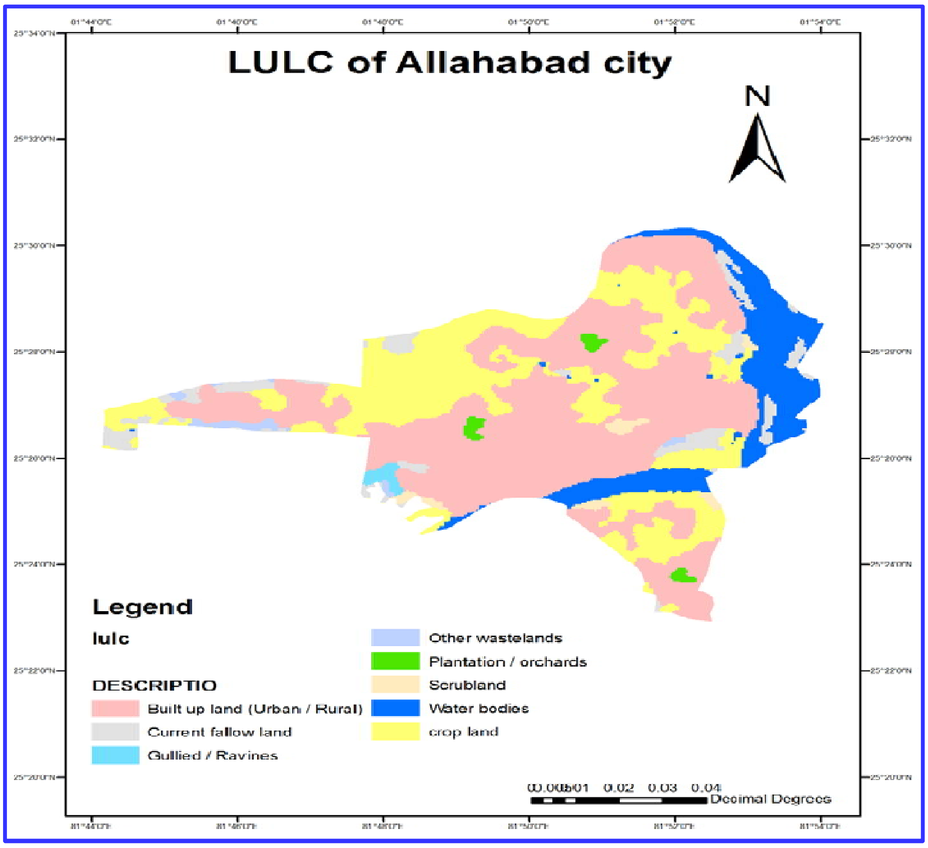

Fig. 2: Landuse land cover map of Allahabad city

3.4 Slope

Slope is one of the important terrain parameters which are explained by horizontal spacing of the contours. In general, in the vector form closely spaced contours represent steeper slopes and sparse contours exhibit gentle slope whereas in the elevation output raster every cell has a slope value. Here, the lower slope values indicate the flatter terrain (gentle slope) and higher slope values correspond to steeper slope of the terrain (Figure 5).

Based on the thematic maps of different parameters (landuse/landcover, geomorphology, lithology and slope) and by using weighted overlay method different weights were given to individual parameter and scores were calculated (Table 4). It can be observed from the table 4 that geomorphology is very sensitive towards groundwater potential. The groundwater potential map (Figure 6) demonstrates that the excellent groundwater potential zone is concentrated in the north-eastern and north-east region of the study area due to the distribution of alluvial plains and agricultural land with high infiltration ability. About 43.44 km^2 of the total areafalls under the ‘very poor’ zone, 21.56 km^2 falls under ‘poor’ zone,18.89 km^2 falls under moderate zone and 12.61 km^2 is come under ‘very good’ groundwater potential zone. Finally, the cumulativeeffect of the weighted multi influencing factors through overlayanalysis in GIS platform revealed the mapping of groundwaterpotential zones in the study area.

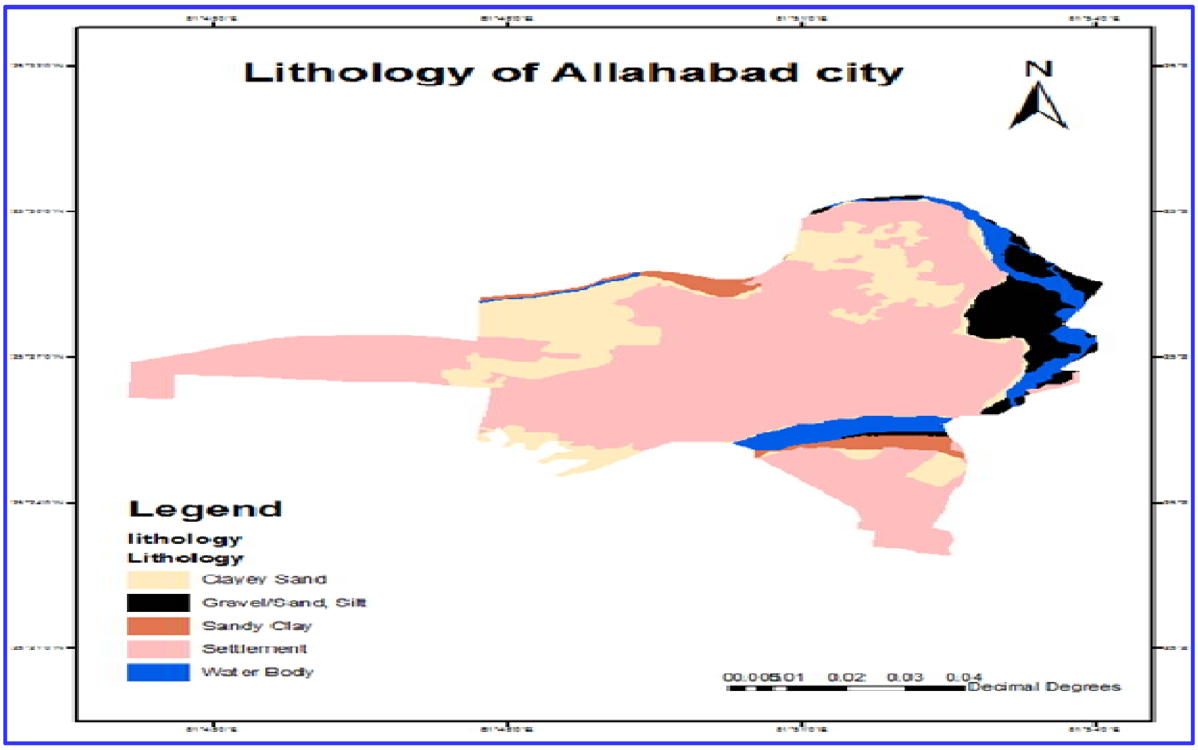

Fig. 3: Lithology map of Allahabad city

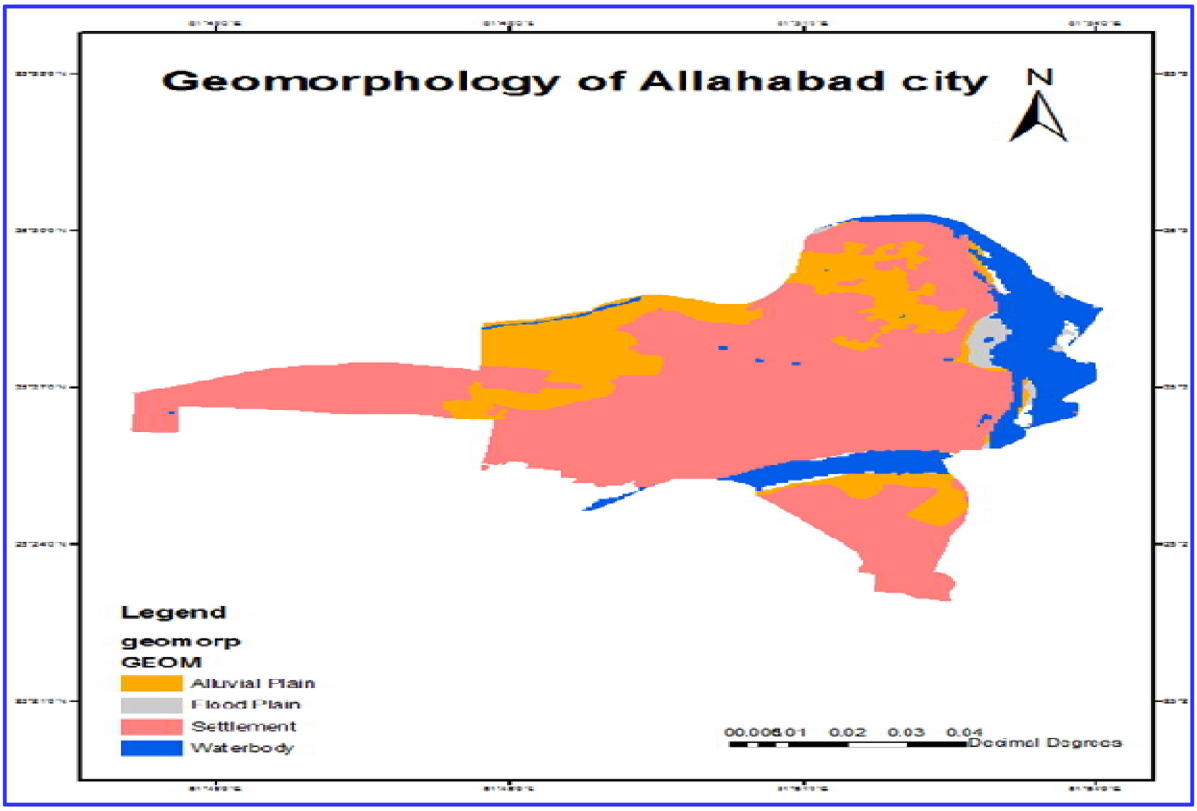

Fig. 4: Geomorphology of Allahabad city

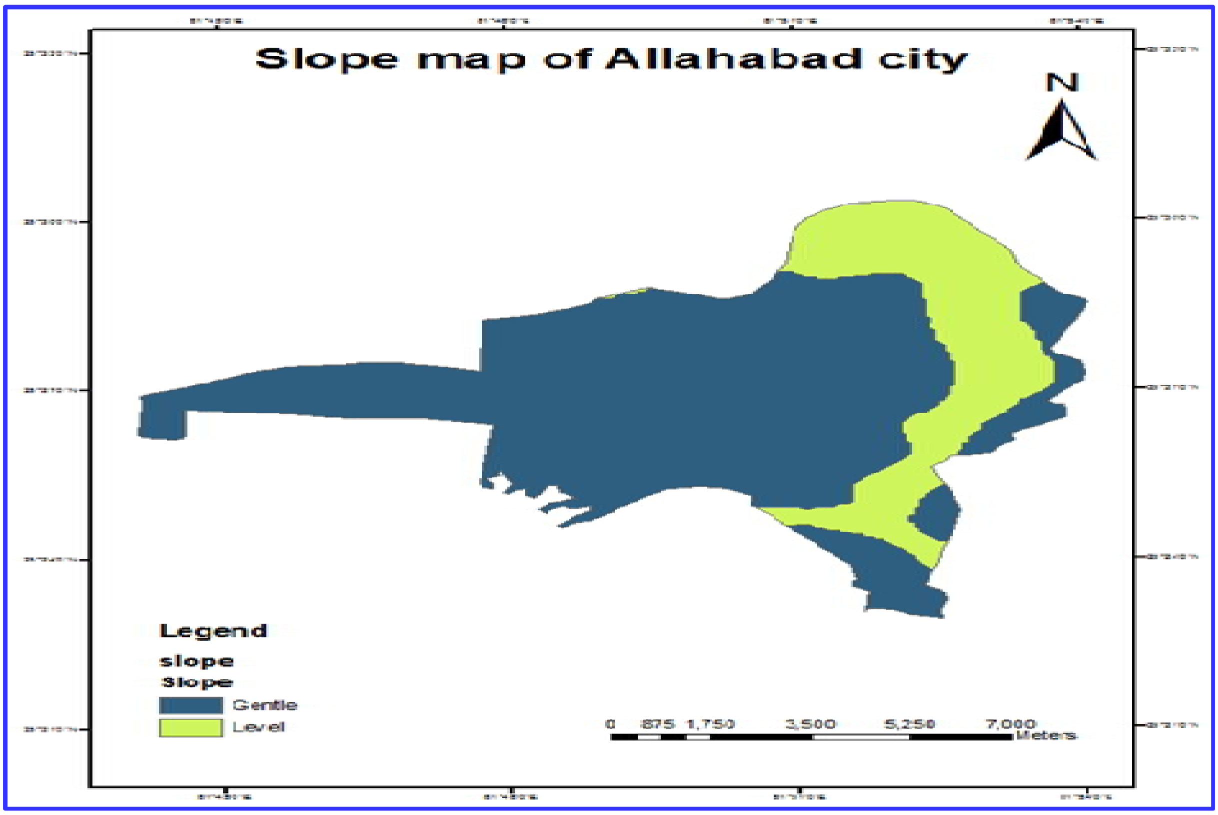

Fig. 5: Slope map of Allahabad city

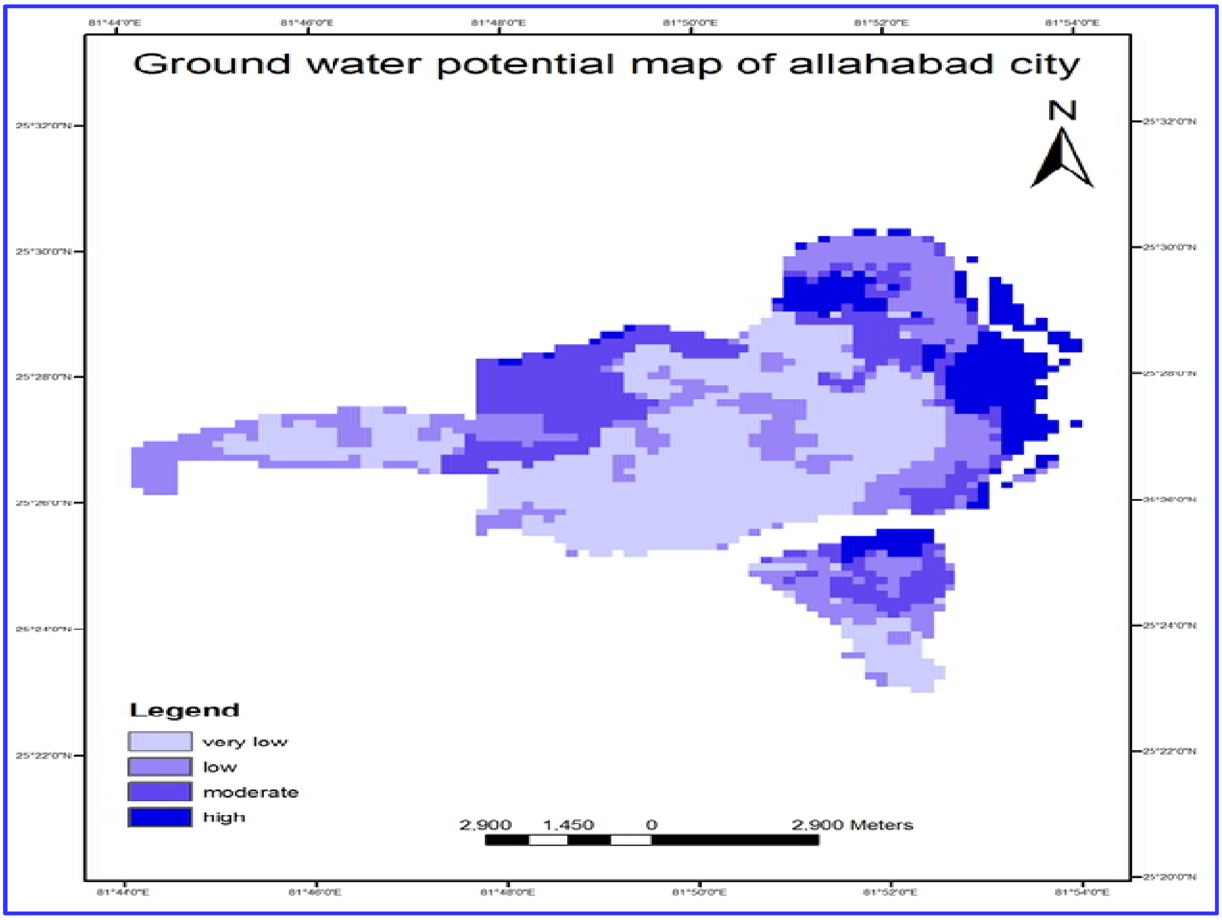

Fig. 6: Ground water potential map of Allahabad city

Table 4. Rank for different parameter of groundwater potential zone

Parameters	class	Rank	Weight	Score
Land use land cover	Built up land (Urban / Rural)	1	25	25
	Current fallow land	3		75
	crop land	4		100
	Gullied / Ravince	3		75
	Other wasteland	2		50
	Plantation / Orchards	4		100
	Scrub land	2		50
	Water bodies	5		125
Lithology	Clay with sand/Silt parting	3	20	60
	Clayey sand	2		40
	Gravel/Sandy, silt	3		60
	Settlement	1		20
	Water body	5		100
Geomorphology	Alluvial plain	4	30	120
	Flood plain	5		150
	Settlement	1		30
	Water body	5		150
Slope	Gentle	3	25	75
	level	5		125

4. SUMMARY & CONCLUSION

Satellite imageries and conventional data were used to prepare the thematic layers of lithology, slope, geomorphology and land-use. The various thematic layers are assigned proper weightage through Weighted overlay technique and then integrated in the GIS environment to prepare the groundwater potential zone map of the study area. According to the groundwater potential zone map, Allahabad city is categorized into four different zones, namely ‘very low’, ‘low’, ‘moderate’, and ‘high which cover 43.44 km^2, 21.56 km^2, 18.89 km^2, 12.61 km^2. The results of the present study can serve as guidelines for planning future artificial recharge projects in the study area in order to ensure sustainable groundwater utilization. This is an empirical method for the exploration of groundwater potential zones using remote sensing and GIS, and it succeeds in proposing potential sites for groundwater zones. This method can be widely applied to a vast area with rugged topography for the exploration of suitable sites.

Delineating the groundwater potential zones in Allahabad city, India using remote sensing, GIS and Weighted overlay techniques is found efficient to minimize the time, labor and money and thereby enables quick decision-making for sustainable water resources management.

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